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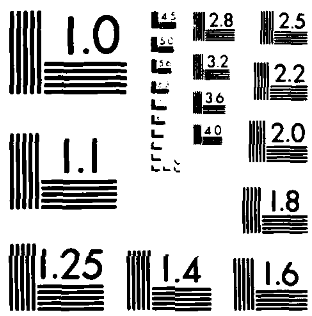

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Characterization of Atmospheric Conditions Along Transmission Paths from a Remotely Piloted Vehicle

Final Report
FRI-84-AR-140

Electrical Engineering Department
The University of Texas at El Paso

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A remotely piloted vehicle (RPV), designated as the Maneuverable Atmospheric Probe (MAP), was instrumented for characterizing and mapping of the optical scattering properties of the atmosphere. This was accomplished by incorporating on the MAP a light and compact forward scattering nephelometer for performing insitu measurements of the total scattering coefficients from approximately .03 km^{-1} to 300 km^{-1}, corresponding to visibilities from 100 km and 10 m, respectively. The MAP is also instrumented to perform atmospheric measurements of pressure, temperature, relative humidity, temperature and optical structure

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20. functions (C_T^2, C_n^2) and particulate sampling. Based on theoretical and laboratory studies, as well as actual flight tests, it is concluded that the MAP may be utilized to completely characterize the optical scattering and refractive properties of the atmosphere resulting from its aerosol, turbulent and temperature structure.

CHARACTERIZATION OF ATMOSPHERIC CONDITIONS ALONG TRANSMISSION PATHS FROM A REMOTELY PILOTED VEHICLE

FINAL REPORT

FRI-84-AR-140

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FEBRUARY 15, 1984

U.S. ARMY RESEARCH OFFICE

CONTRACT DAAG29-80K-0091

ELECTRICAL ENGINEERING DEPARTMENT
THE UNIVERSITY OF TEXAS AT EL PASO

Abstract

A remotely piloted vehicle (RPV), designated as the Maneuverable Atmospheric Probe (MAP), was instrumented for characterizing and mapping of the optical scattering properties of the atmosphere. This was accomplished by incorporating on the MAP a light and compact, foward-scattering nephelometer for performing insitu measurements of the total scattering coefficients from approximately .03 km^{-1} to 300 km^{-1}, corresponding to visibilities of 100 km and 10 m, respectively. The MAP is also instrumented to perform atmospheric measurements of pressure, temperature, relative humidity, temperature and optical structure functions (C_T^2, C_n^2) and particulate sampling. Based on theoretical as well as actual flight tests, it is concluded that the MAP may be ~~utili~~zed to completely characterize the optical scattering and refracting properties of the atmosphere resulting from its aerosol, turbulent, and temperature structure.

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1. Introduction

This final report summarizes the work accomplished from September 1980 through December 31, 1983, under U.S. Army Research Office (ARO) contract DAAG 29-80K-0091, "Characterization of Atmospheric Conditions along Transmission Paths from a Remotely Piloted Vehicle." This effort was also sponsored in part by the U.S. Army Atmospheric Sciences Laboratory, White Sands Missile Range (WSMR), NM.

The objective of this study was to determine the feasibility of instrumenting ASL's Maneuverable Atmospheric Probe (MAP), for characterizing and mapping of the optical scattering properties of the atmosphere. In order to accomplish this objective, a compact and lightweight, forward scattering nephelometer was adapted to the MAP for performing insitu measurements of the total light scattering coefficients and visibility. In addition, the nephelometer was calibrated and correlated with actual particular characteristics captured with on board and ground based particulate impactors.

Based on laboratory and actual flight tests, it is concluded that on board MAP measurements with the nephelometer provide a viable means of measuring and mapping of light scattering and visibility of the atmosphere. Since the MAP is also instrumented to perform insitu measurements of the temperature and optical transfer function (C_T^2 and C_n^2) as well as other meteorological parameters the MAP may be utilized for mapping the meteorological and atmospheric optical properties of scattering and turbulence as a function of altitude or along a designated path.

The following is a list of publications and technical reports resulting from this contract:

1. Ballard, H. N., McDonald, C. and M. Izquierdo, "Remotely Piloted Vehicle Measurements of Meteorological Parameters at White Sands Missile Range", 1981 Fall Meeting, American Geophysical Union, December, 1981.

2. Ballard, H. N. , Izquierdo, M., McDonald, C., Rubio, R. and M. L. Hill, "The Maneuverable Atmospheric Probe (MAP), A Remotely Piloted Vehicle", Atmospheric Sciences Laboratory, TR-0110, White Sands Missile Range, NM. May, 1982.

3. Ballard, H. N., Izquierdo M, and McDonald, C. "The Maneuverable Atmospheric Probe (MAP), A Remotely Piloted Vehicle", Schellenger Research Laboratories Interium Report 1R1-81-WS-113, The University of Texas at El Paso, August, 1982.

4. Dominguez, D., et al. "Time Constant Measurements for Coil Wires", Schellenger Research Laboratories, Special Report, SP1-82-AR-134, The University of Texas at El Paso, TX. November , 1982. (Master's Thesis).

5. Quintana, F. et al. "A Low Power Microprocessor Controlled Data Acquisition System for Airborne Applications", Schellenger Research Laboratories SP-82-AR-135, The University of Texas at El Paso, November, 1982. (Master's Thesis).

6. Gonzalez, R., et al., "Feasibility Studies of Electromagnetic Induction of the Geomagnetic Field for Determining Ground Speed", Electrical Engineering Department, SP2-82-AR-135, The University of Texas at El Paso June, 1983 (Master's Thesis).

7. Tsang, S. A., et al., "A Microcomputer Based Data Acquisition System for Real Time Display and Processing of Meteorological Data obtained from a Remotely Piloted Vehicle", SP2-82-AR-135, The University of Texas at El Paso Electrical Engineering Department, December 1983 (Master's Thesis).

8. Alvarado, C., et al., "Comparisons Between the 1550B and the HSSVR101 Nephelometers", Electrical Engineering Department, SP2-82-AR-1, The University of Texas at El Paso, November 1983.

9. McDonald, C., et al., "Remotely Piloted Vehicle Mappings of Visibility and Desert Aerosols at White Sands Missile Range", 1983 Fall Meeting American Geophysical Union, San Francisco, December 1983.

10. Smith, J., et al., "Velocity Corrections C_T-C_N^2 Measurements", 1983 Fall Meeting, American Geophysical Union, San Francisco, December 1983.

11. Izquierdo, M. et al., "Instrumenting an Unmaned Aerial Vehicle (UAV) with Meteorological and Aerodynamic Sensors", 1983 Fall Meeting, American Geophysical Union, San Francisco, December 1983.

Scientific Personnel supported under this contract were as follows:

Dr. Carlos McDonald, Co Principal Investigator

Mr. Miguel Izquierdo, Co Principal Investigator

Mr. Harold N. Ballard, Physicist

*Mr. Fernando Quintana, Graduate Assistant

*Mr. Carlos Alvarado, Graduate Assistant

Mr. Rodolfo Velasquez, Graduate Assistant

Mr. Carlos Herrera, Technical Staff Assistant

Mr. Luis A. Yip, Technical Staff Assistant

Ms. Juana P. Mejia, Student Assitant

Mr. John R. Corbin, Student Assistant

Dr. Jack Smith, Co Investigator

Mr. Alvaro Galdos, Student Assistant

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Mr. Jose A. Herrera, Student Assistant

Mr. Bobby Martinez, Student Assistant

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*Mr. Raul Gonzalez, Graduate Assistant

Mr. Francisco J. Tostado, Student Assistant

*Mr. Steve Tsang, Graduate Assistant

*Mr. Danny Dominguez, Graduate Assistant

A description of the work accomplished is included in the following sections. Section 2 describes the MAP instrumentation and telemetry system. Section 3 describes the experimental flights and results, and Section 4 is devoted to conclusions and recommendations.

* Earned Master's Degrees while working on contract projects.

2. The Maneuverable Atmospheric Probe (MAP)

2.1 General Description

Under previous contracts with ASL, The University of Texas at El Paso's Electrical Engineering Department instrumented an RPV, designated as the MAP, with meteorological sensors, particulate samplers, aerodynamic sensors and ancillary electronics [1,2,3]. With the incorporation of a nephelometer, the MAP provides a safe and relatively inexpensive platform for performing optical and meteorological measurements along designated paths or with respect to altitude. In addition to light scattering measurements and particulate capture, the MAP is instrumented for measuring atmospheric pressure, temperature, humidity, C_T^2, C_n^2 (temperature and optical structure functions) yaw and pitch gust, and the earth's electric and magnetic field. The MAP is also instrumented for measuring aerodynamic parameters, including air speed, angle of attack and engine rpm. With the on board aerodynamic instrumentation (including a fluidic gyro and electrostatic stabilizer) and radar tracking, determination of the horizontal wind component is also possible.

A photograph of the MAP is shown in Fig. 2.1. The physical and aerodynamic characteristics of the MAP are summarized in Fig. 2.2 and Table 2.1. A list of the current MAP sensors are included in Table 2.2. A complete description of the MAP and sensor instrumentation is included in References [3,12,13].

2.2 MAP Nephelometer

The MAP nephelometer is a commerical forward scatter visibility meter (model VR101, HSS Inc., Bedford, Mass.). Its output voltage is proportional to the total (volume) scattering coefficient derived from 0.88 um light

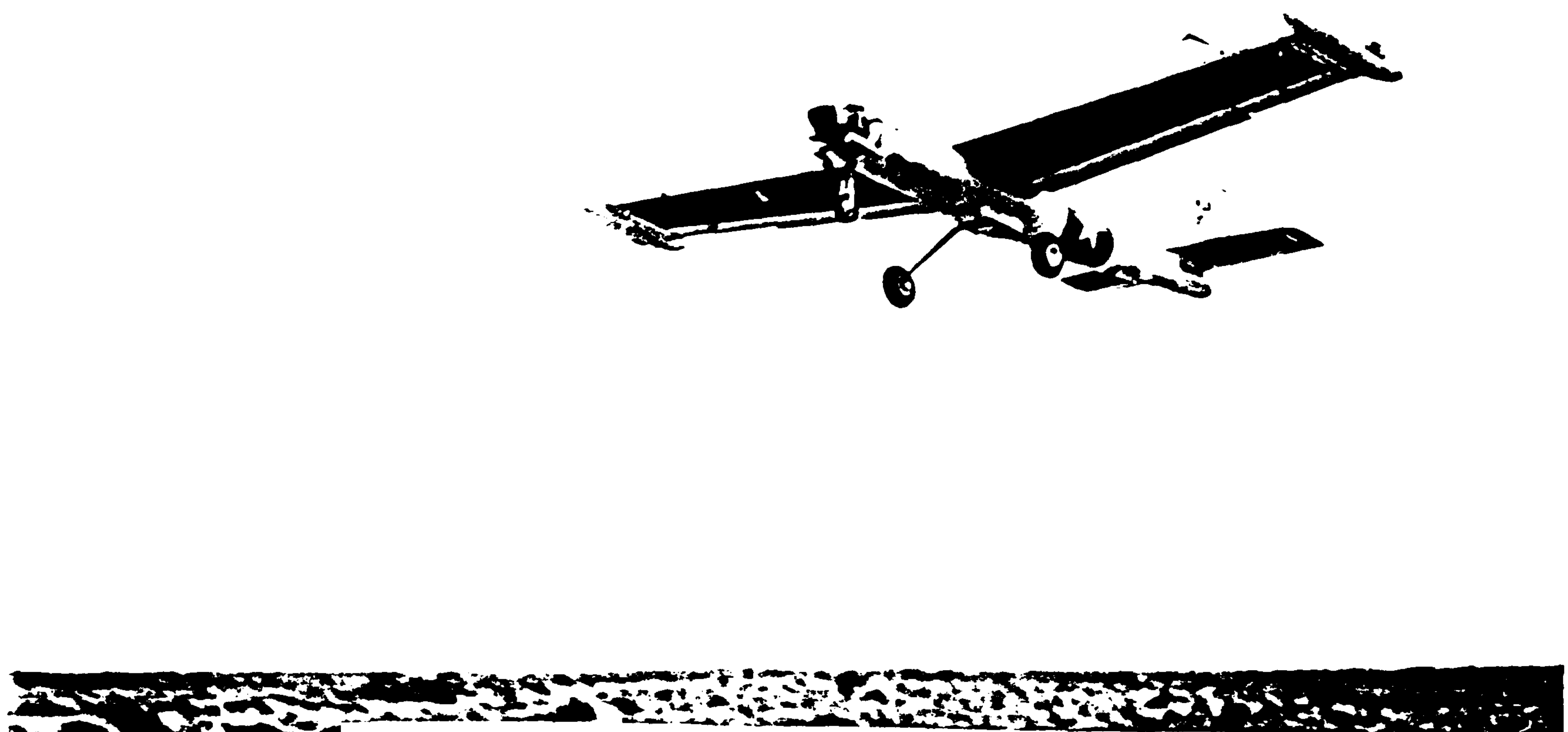


Figure 2.1 Maneuverable Atmospheric Probe (MAP)

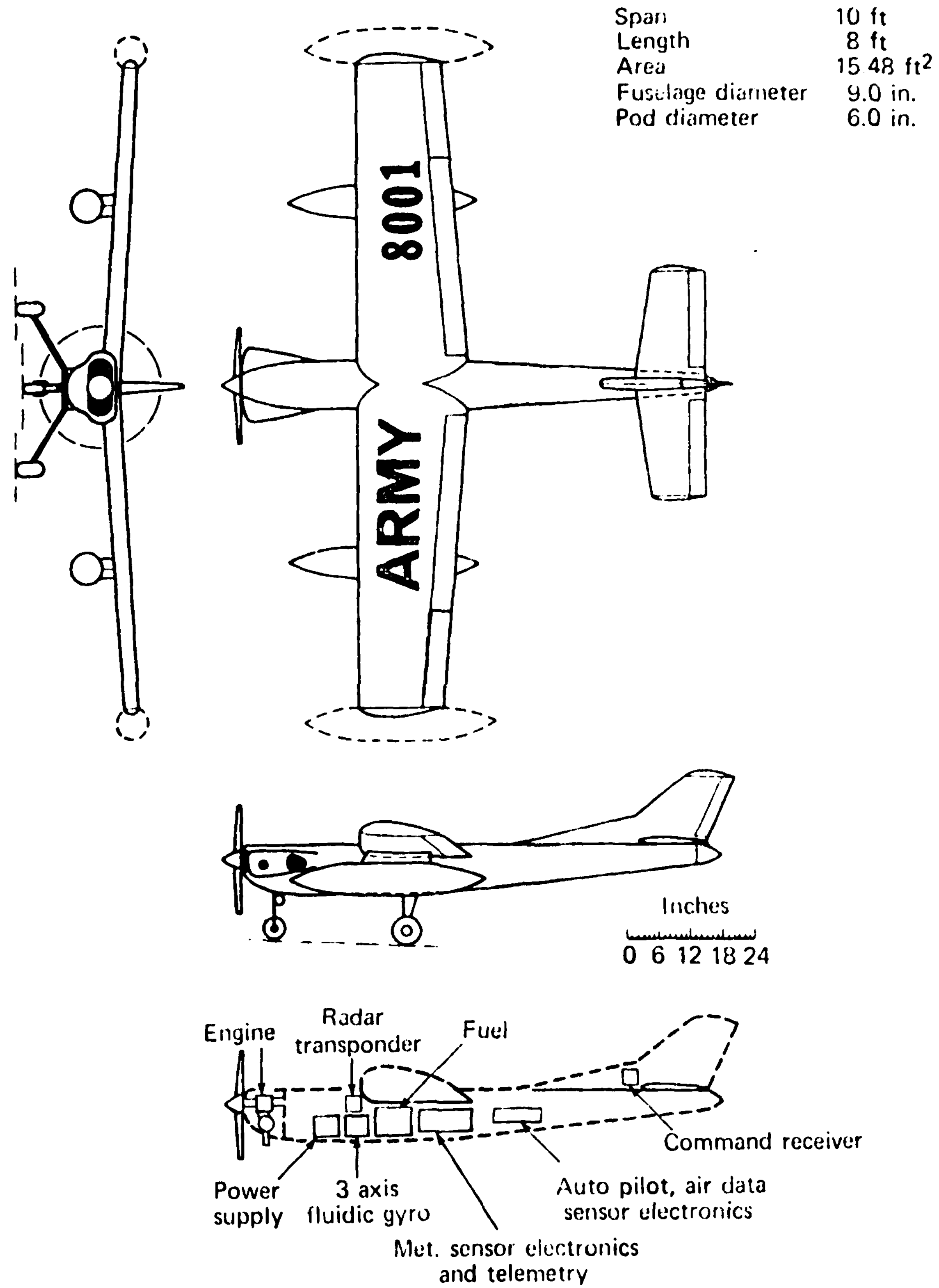


Fig. 2.2. MAP Vehicle and Major Components.

Gross Weight	80.0 Lbs.
Installed Power	5.0 S.H.P.
V_{stall} Sea-Level (with Flaps)	32 M.P.H.
V_{stall} 11,000 Ft. (with Flaps)	40 M.P.H.
$V_{min.\ power}$ Sea-Level	43 M.P.H.
$V_{min.\ power}$ 11,000 Feet	51.0 M.P.H.
$V_{L/D\ max}$ Sea-Level	55 M.P.H.
$V_{L/D\ max}$ 11,000 Feet	65 M.P.H.
V_{max} Sea-Level	107 M.P.H.
V_{max} 11,000 Feet	104 M.P.H.
Rate of Climb Sea-Level	1,280 ft/min.
Rate of Climb 11,000 Feet	800 ft/min
Practical Ceiling (R/C = 100 ft/min)	26.5 K ft.
Absolute Ceiling	29.5 K ft.
Min: Sink Speed (unpowered) Sea-Level	400 ft/min
Min: Sink Speed (11,000 ft.)	460 ft/min
Duration at Full Power (S.L.) w. 10% reserve	1.8 hrs.
Duration at Optimum Cruise S.L. 10% reserve	7.5 hrs.
Duration at Optimum Cruise 11,000 ft. 10% reserve	7.0 hrs.
Max. Total Range Sea Level	412 Miles
Max. Total Range 11,000 ft.	455 Miles

Table 2.1. Principle Characteristics of the MAP.

Wing Span	10.0 Feet
Wing Area	14.58 Sq. Feet.
Aspect Ratio	6.86
Length	7.75 Feet
Fuselage Diameter	9.0 Inches
Pod Length	1.0 Feet to 3 Feet.
Pod Diameter	6.0 Inches
Engine Weight	7.0 Lbs.
Air Frame Weight	23.5 Lbs.
Control Equipment	6.0 Lbs.
Payload Weight	25.0 Lbs.
Fuel Weight (2 Hrs. at Max. S.L. Power)	12.0 Lbs.

Table 2.1. Principle Characteristics of the MAP (Continued).

1. Nephelometer (HSS VR101, forward scatter).
2. Air temperature (Gaulton 40 mil termistor).
3. Air Pressure (National Semiconductor 1702A).
4. Relative Humidity (Standard Weather Bureau Hygristor and capacitance type (Vaisala).
5. Temperature Structure Function (temp. difference-20 cm separation).
6. Temperature Structure Function (temp. difference-2.8 m separation).
7. Particulates (0.25-16 microns) (PIXIE 7-stage Cascade impactor).
8. Particulates (.1-100 microns) (UTEP multistage impactor).
9. Electric Field Components (X, Y, Z).
10. Magnetic Field Components (X, Y). (Magnetometer).
11. Air Speed. (Pitot Tube).
12. Gust (Pitch & Yaw).
13. Altitude. (Altimeter).
14. Engine RPM. (APL Tachometer).
15. Electrostatic Stabilizer

Table 2.2. Meteorological and Aerodynamic Sensors on the Maneuverable Atmospheric Probe (MAP).

scattered from a free volume of air, one cm^3. Basically, it consists of an infrared emitting diode (IRED), a photovoltaic detector, lens system, housing and ancillary electronics. Modulated light from the IRED is forward scattered from a 1 cm^3 free volume of air and is picked up by the detector. The output voltage proportional of the signal is synchronously detected, amplified, and corrected for the variation of IRED intensity.

As verified theoretically and experimentally, the output voltage is proportionalto the total scattering coefficient for a given aerosol distribution. However, the forward scattering is also dependent on the index of refraction of the scattering particles [4]. In practice, this effect was compensated by calibration in a given aerosol against a total integrating nephelometer, such as the MRI 1550B.

The HSS VR101 nephelometer is light (5 lbs.), compact, rugged, and only requires four watts of power to operate (without dew windows). It exhibited some electronic drift instability, but this has been corrected by a circuit modification by the manufacturer. Fig. 2.3 shows a photograph of the nephelometer and Table 2.3 summarizes the manufacturer's specifications.

For MAP application, the instrument was mounted inside underneath the wing (see Fig. 2.4). A logarithmic amplifier (see Fig. 2.5) was used to couple the nephelometer output to an on board IRIG telemetry channel. Generally, the instrument operated satisfactorily in flight, independent of mechanically vibration and aerodynamic effects.

2.3 MAP Telemetry

A pictorial diagram of the overall MAP telemetry and recording system is shown in Fig. 2.6. The sensor data from the MAP (see Table 2.2) was telemetered by an on board FM/FM IRIG telemetry system operating at 1526 MHz.

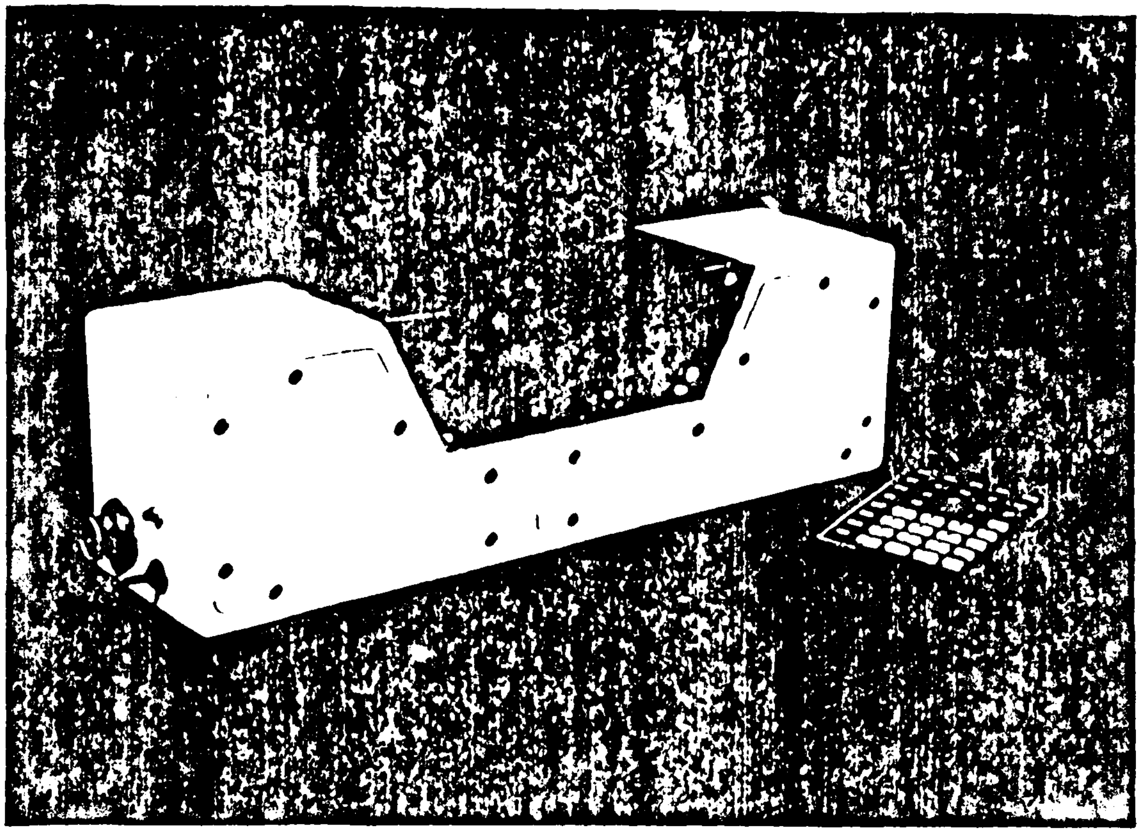


Fig. 2.5. HSS Model VR-101 Forward Scattering Nephelometer.

2 Alfred Circle
Bedford, Ma. 01730
(617) 275-2020

HSS INC
TECHNICAL DATA SHEET

Model Developmental(1)
Sheet 2 of ___
Date 5 Oct 1981

MODEL VR101 VISIBILITY METER

PERFORMANCE CHARACTERISTICS

The performance characteristics stated below are based on a time constant of 15 seconds for the electronic circuitry of the VR101 and the ability of the readout or recording system to cover the full output signal range (0 to 10 volts) of the VR101 with appropriate resolution.

Visual Range Coverage

Maximum (Very Light Haze) . . . . 100 kilometers
Minimum (Very Heavy Fog) . . . . 10 meters

RMS Noise Voltage (At Output) . . . . 1 millivolt

Linear Dynamic Range . . . . 10^4 to 1

Stability (Design Goals --- Untested):

Short Term Drift . . . . < 1 per cent
Long Term Drift . . . . < 10 per cent/year

Source Characteristics:

Type . . . . LED
Bandwidth . . . . 0.84 to 0.92 μm
Lifetime . . . . > 10 years

Servicing (Design Goals--Untested)

Mean Time for Replacement of Any Component.

(Continuous Operation) . . . . Several Years

Calibration Check (Insert Reference Standard; Note Reading) . . . . Semi Annually

Clean Windows . . . . Monthly

SPECIFICATIONS

Analog Output, proportional to the scattering coefficient . . . . .0 to 10 volts

Response Time . . . . 15 seconds

Size . . . . 3.5 "W x 4.5"Hx 14.5"L

Weight . . . . .4 lbs

Table 2.3. Manufacturer's Specifications of the Model VR-101 Nephelometer.

HSS INC
2 Alfred Circle
Bedford, Ma. 01730
(617) 275-2020

TECHNICAL DATA SHEET

Model Developmental[1]
Sheet 3 of
Date 5 Oct 1981

MODEL VR101 VISIBILITY METER

SPECIFICATIONS (Cont)

Power Requirements:

(With No-Dew Windows)	10 Watts
(Without No-Dew Windows)	4 Watts
Power Source	28 V DC

Environmental:

Temperature	-35 °C to 50 °C
Altitude	0 to 10,000 ft
Weather	All-Weather

NOTE (1):

Information on this developmental model instrument is intended for evaluation of the potential usefulness of the instrument in applications other than that for which the sponsor intended. The specifications are subject to change unless otherwise arranged. No obligations are assumed for notice of change. Information furnished by HSS Inc is believed to be accurate and reliable.

Table 2.3. Manufacturer's Specifications of the Model VR-101 Nephelometer (Cont.)

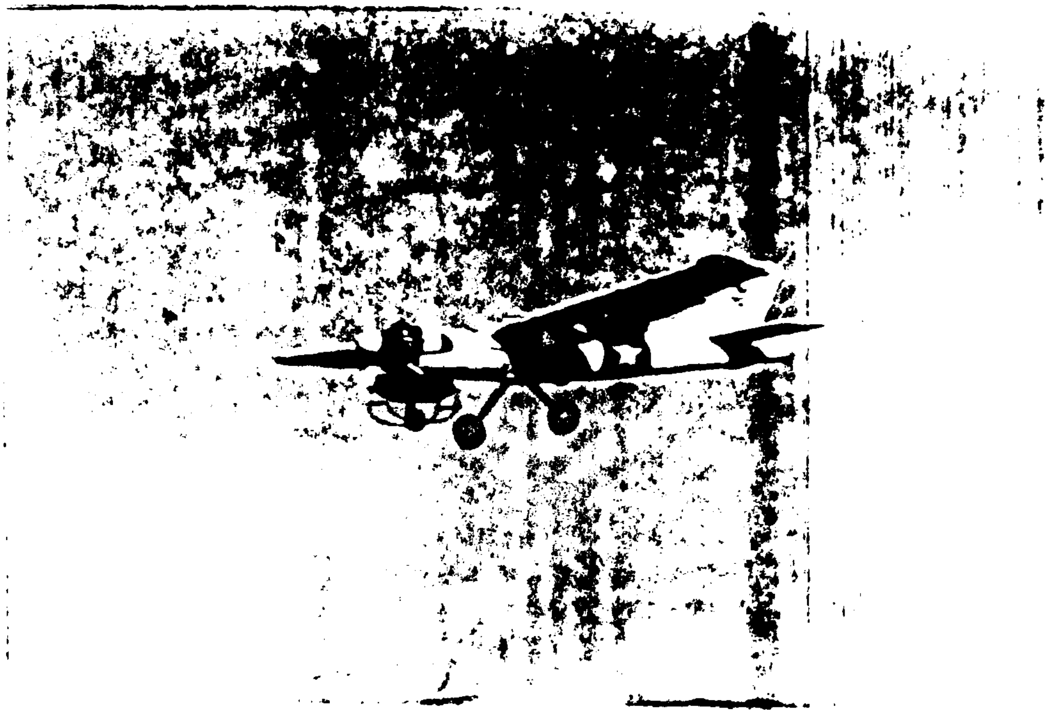


Fig. 2.1. VR-101 Nephelometer mounted underneath the [illegible] in a protective cage enclosure.

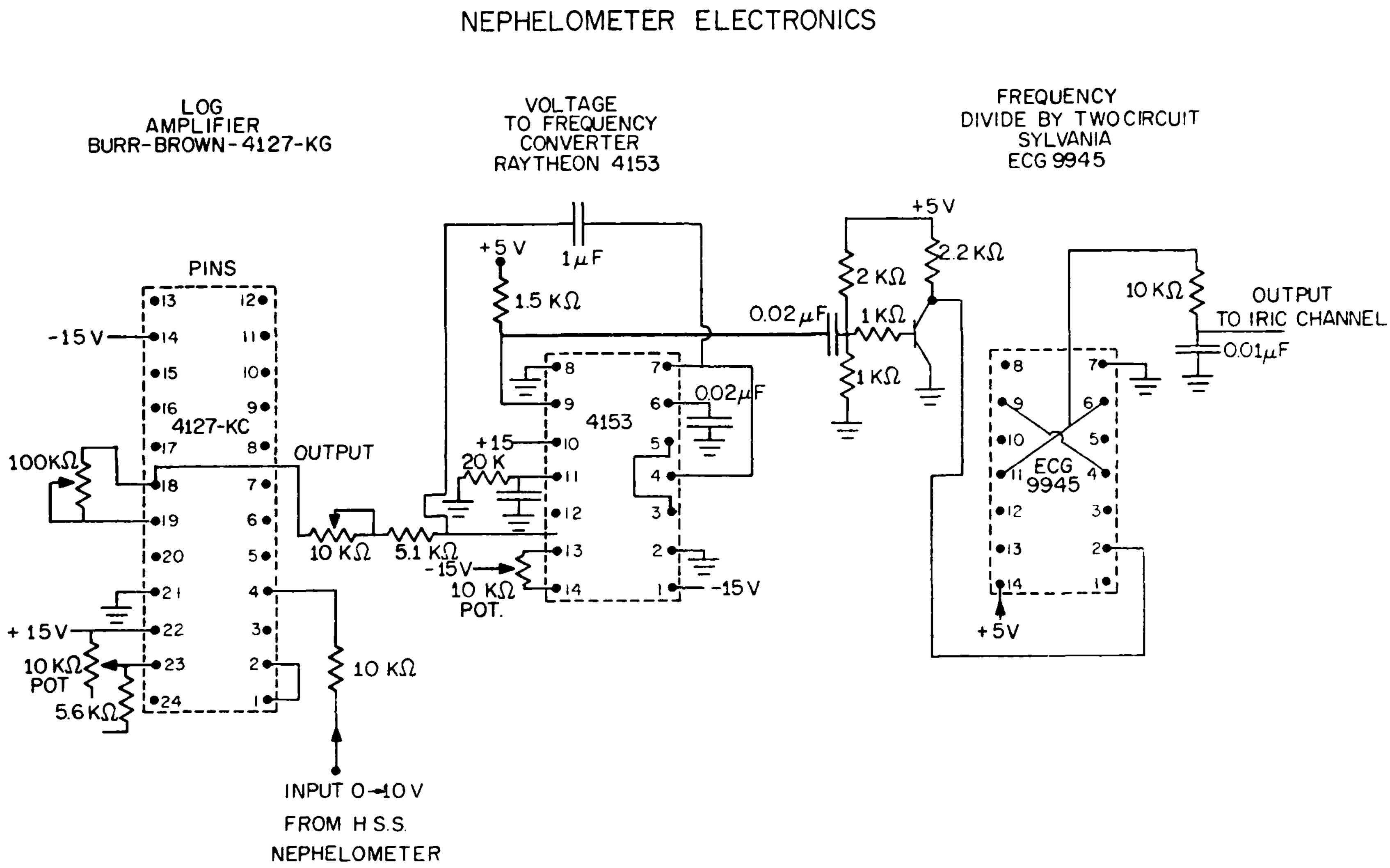


Fig. 2.5. MAP Interface Electronics for the Nephelometer.

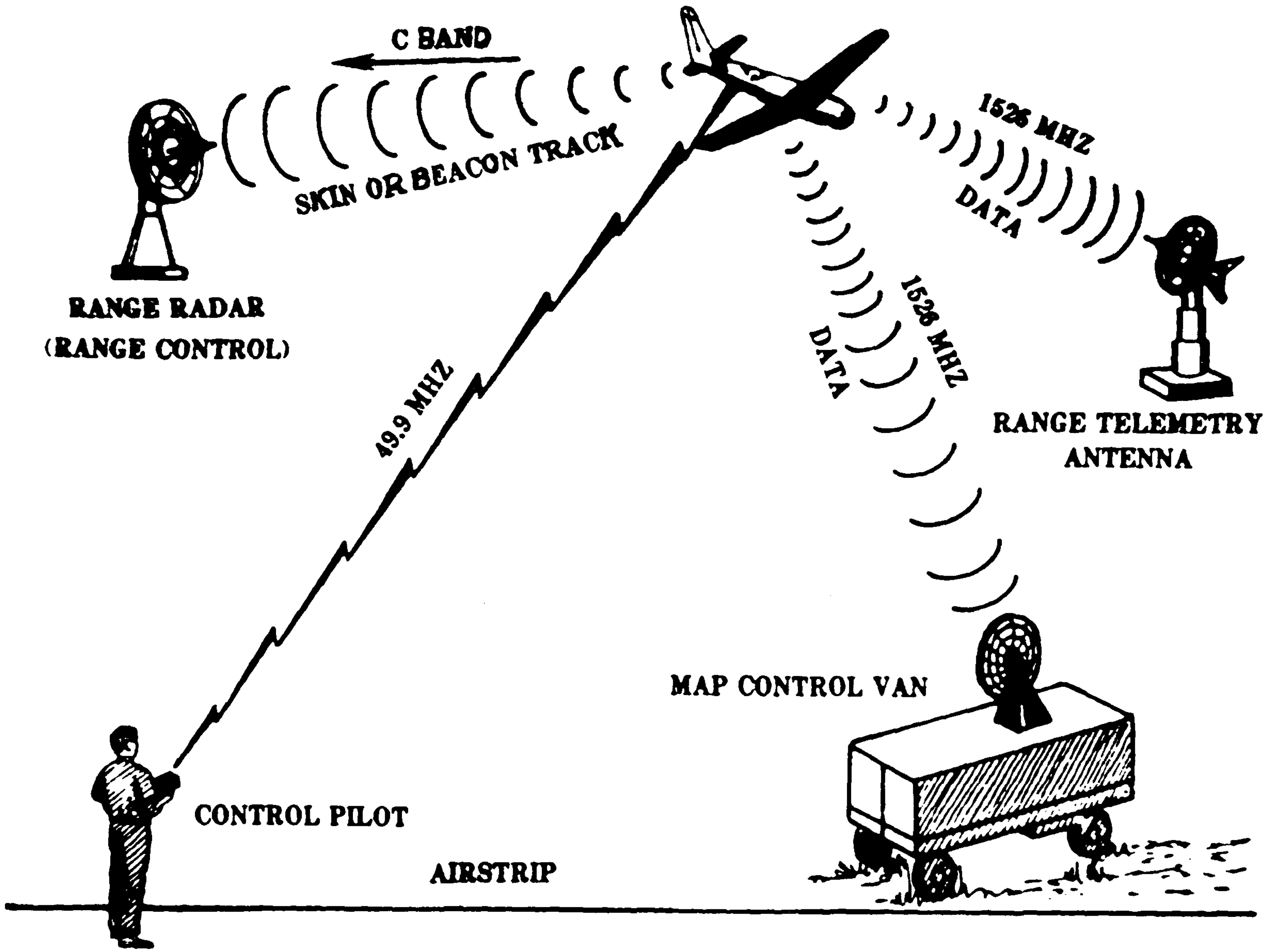


Fig. 2.6. The MAP Telemetry System.

Block diagrams of the on board telemetry system are shown in Fig. 2.7 and 2.8.

Remote control of the MAP by ground-based pilot was accomplished by Kraft transmitter/controller for radio control planes, where the RF signal consists of a time multiplexed, pulse width signal corresponding to proportional controls for the ailerons, flaps, rudder and throttle for the engine rpm control. The 49.95 MHz RF signal was detected and demodulated by an on board antenna-receiving system for detection, demultiplexing and generating the control signals for the servo system flight controls. Fig 2.8 includes a block diagram of the MAP's 49.95 MHz receiver and control servo system. A similar system, transmitting at 49.6 MHz, was also used to control the open and closing of the UTEP impactor stages.

As all flight tests were conducted at WSMR, the 1526 MHz, modulated RF signal was received and recorded by WSMR telemetry. For back-up a GFE Van, instrumented by the University, was used as the Ground Receiving Station. The MAP transmission was tracked by a manually operated parabolic antenna. A block diagram of the Ground Receiving Station is shown in Fig. 2.9. The received signal was demodulated and demultiplexed to recover the analog or frequency modulated sensor signals. Those signals were then recorded on a 14 channel analog magnetic tape recorder, where one channel was used to record IRIG-B timing. In addition, the analog or frequency sensor signals and timing were digitized, multiplexed and serially transmitted at 9600 band (RS232) to an LSI microcomputer for digital recording and display.

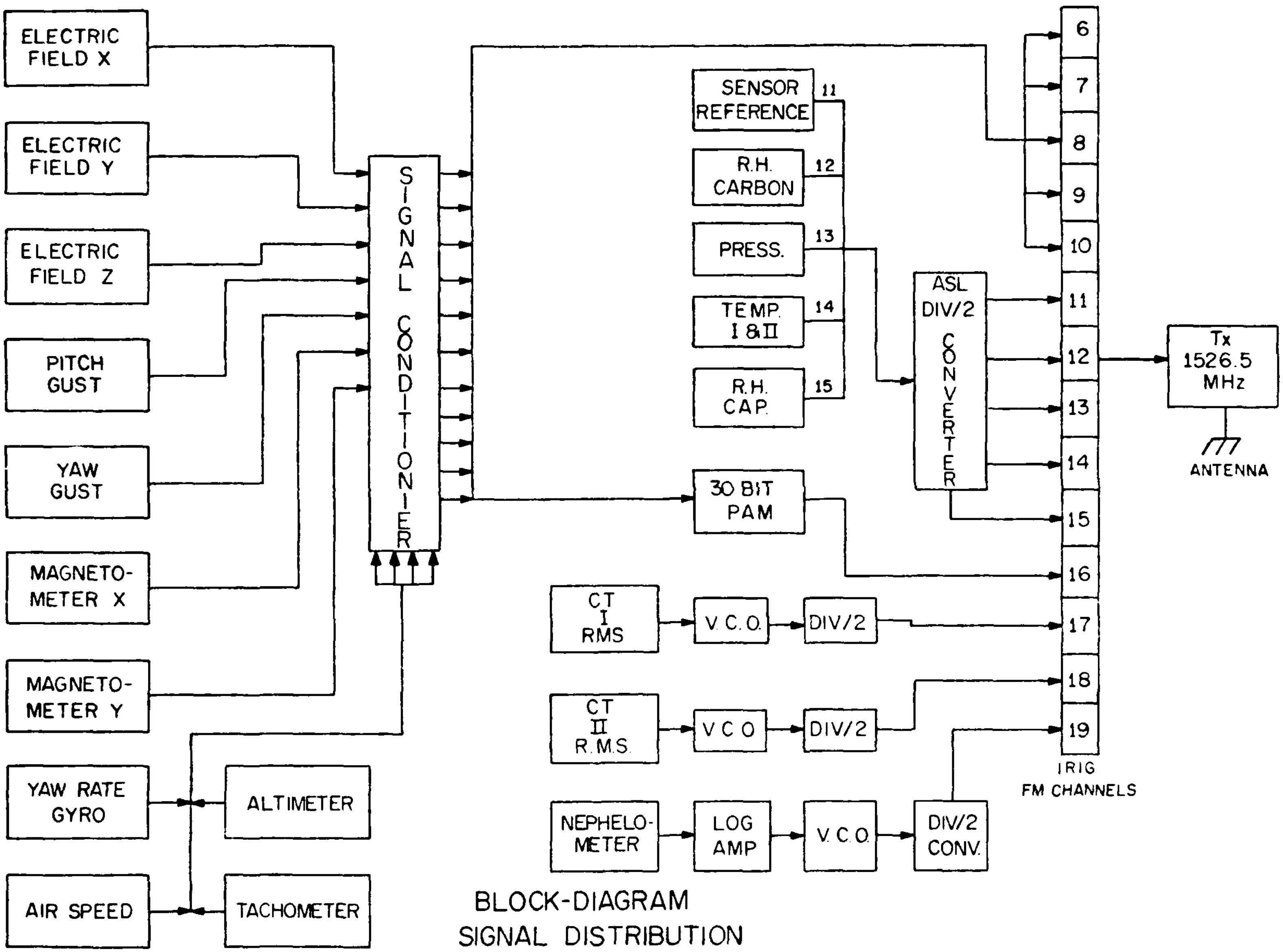


Fig. 2.7. Block Diagram of the MAP's Telemetry System at 1526.5 Mhz.

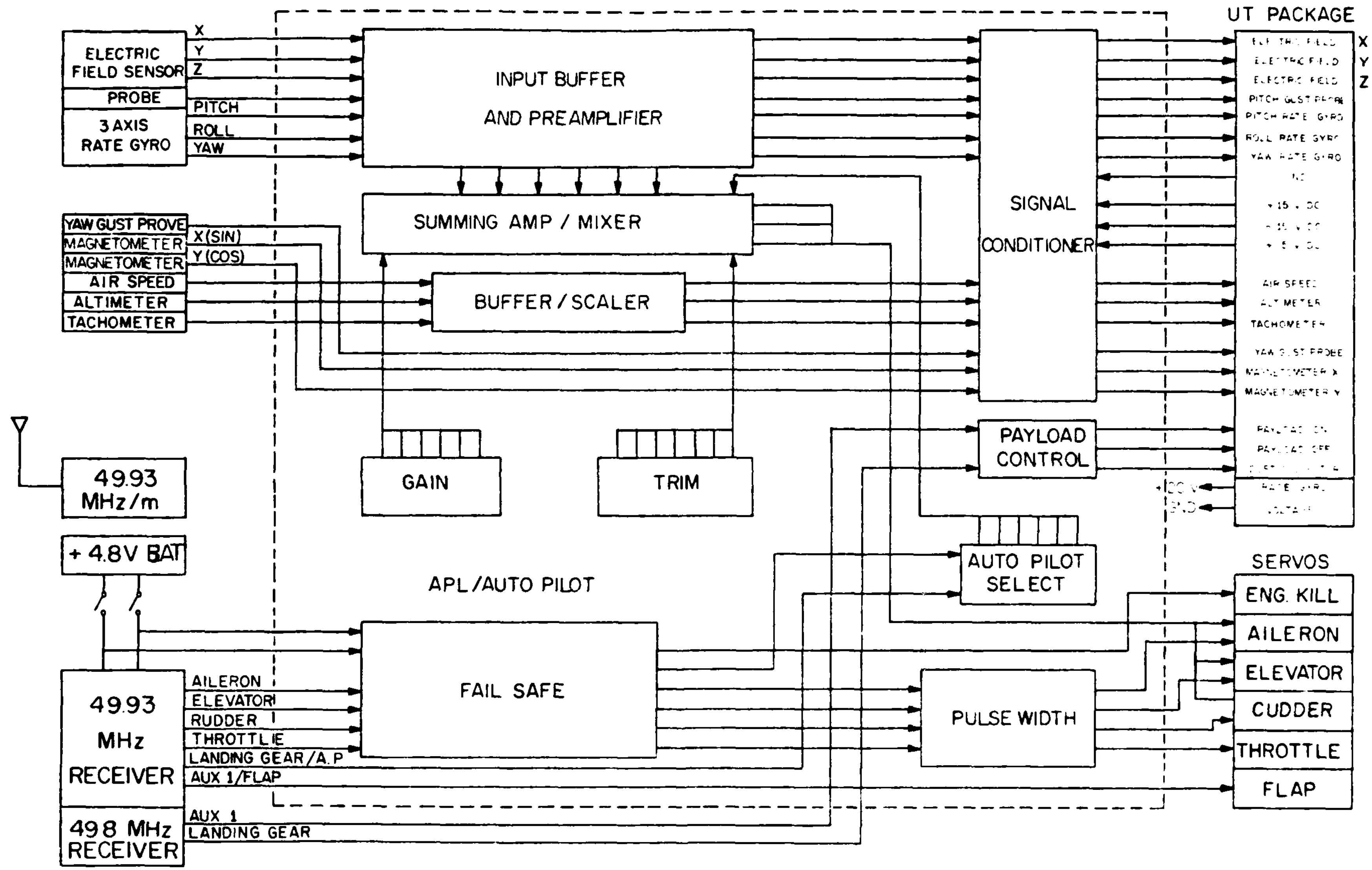


Fig. 2.8. Block Diagram of the 49.93 Mhz MAP Control Receiver and Aerodynamic Sensor interface to the 1526.5 Mhz Telemetry System.

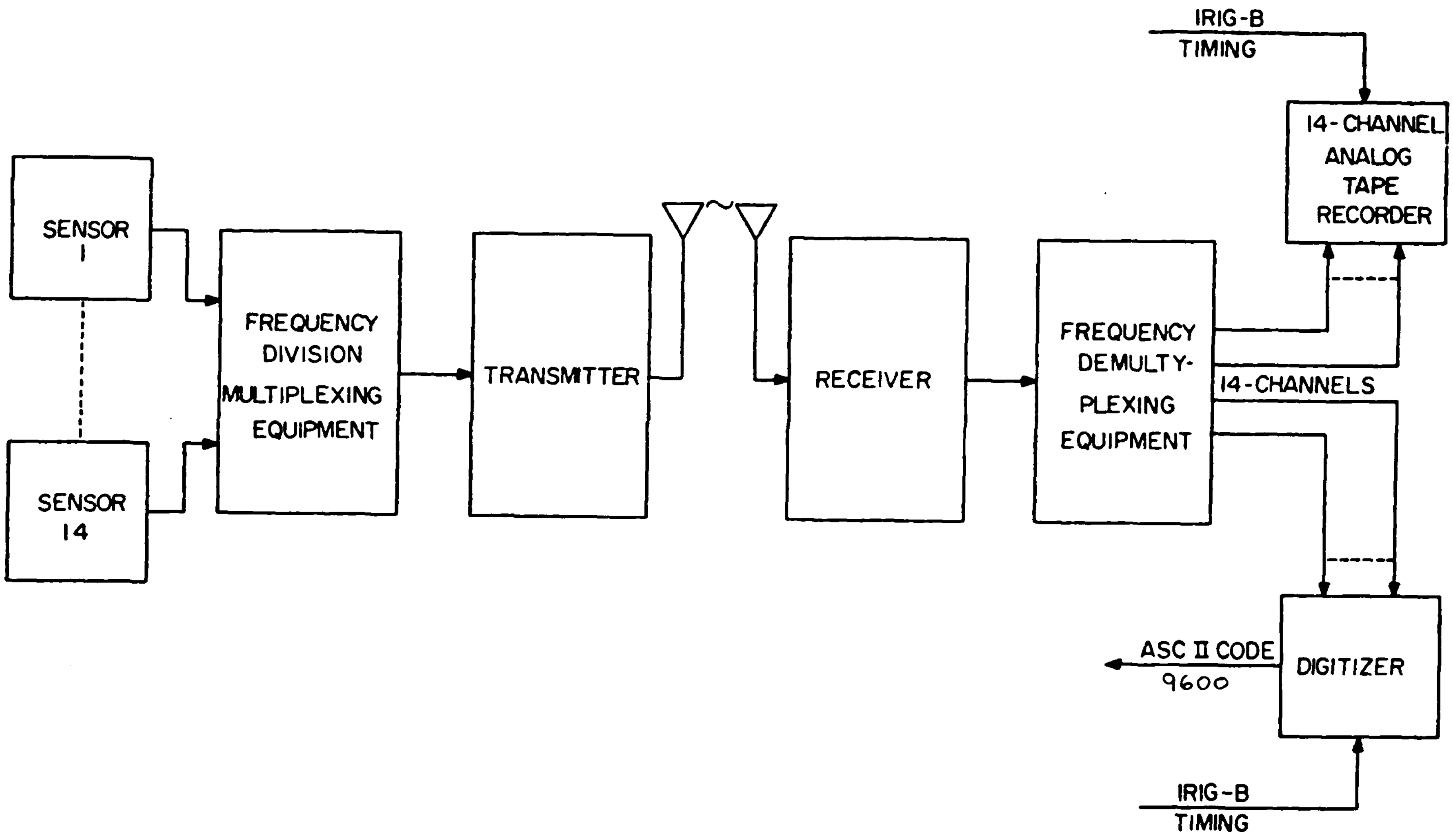


Fig. 2.9. Block Diagram of MAP's Telemetry System including the Ground Receiving and Recording Station.

3.0 Experimental Flights

3.1 Background

During August 26-31, 1982, five MAP flights were conducted at the Oro Grande Test Site, WSMR. Based on ASL's requirements, the purpose of these flights were to demonstrate the MAP's capability of performing the following:

(1) Measurement of the optical scattering properties of the atmosphere as a function of altitude and along designated paths at different meteorological conditions

(2) Determine the time variability of light scattering and C_n^2 along near surface, horizontal paths.

(3) Measurement of other meteorological parameters (temperature, pressure and humidity) as a function of altitude and along flight trajectories.

In order to accomplish the above objectives, the MAP was instrumented as follows:

(a) The HSS VR101 forward scattering nephelometer was utilized to measure the light scattering coefficients and visibility properties of the atmosphere as a function altitude and along the flight trajectories. As a calibration reference, the MRI 1550B intergrating nephelometer was used to monitor light scattering and visibility on the ground.

(b) Samples of desert particulates at various altitudes were captured with a PIXIE cascade and UTEP's multistage impactors during three of the five flights. These samplers were later analyzed with a scanning electron microscope (SEM) to determine the particle concentration and distribution. A second PIXIE was used for ground reference.

(c) C_n^2 was determined from the C_T^2. The latter was computed from differential temperature measurements on the leading edge of the wing with wire temperature sensor pairs mounted 20 cm and 2.8 meters apart, respectively.

(d) Meteorological parameters of air pressure, temperature, relative humidity, pitch and yaw turbulence, and the earth's electric and magnetic components were continuously measured throughout the flights.

3.2 Summary of Flights

During the first three flights of August 24 and 26, 1982, the air worthiness of the MAP was verified and a number of malfunctions related to the engine were corrected. In order not to chance damage on the nephelometer, it was not flown, but was simulated in weight and location.

On August 30 and 31, 1982, the MAP was flown with all the desired instrumentation. This included nephelometer, PIXIE and UTEP particle impactors, differential temperature sensors for measuring C_T^2, atmospheric temperature, pressure, humidity, and aerodynamic parameters which included air speed and engine rpm.

3.3 Meteorological Conditions

The two flights were planned such that during August 30, 1982, the flight trajectory took place in the vertical mixing layer, while the flight of August 31, 1982 took place primarily in a stable region, above the vertical mixing layer. To accomplish this, the flight of August 30, 1982 was planned to take place around noon where solar heating had established a vertical temperature gradient, ($-dT/dZ > 1.2^{o}C/km$) to establish vertical mixing. On August 31, 1982 the flight took place at 0800 MST where a stable atmosphere

still existed above ground, as reflected by the vertical temperature gradient ($-dT/dZ \leq 1.2^{\circ}C/km$). These conditions were verified by examining the radiosonde temperature profile data obtained from nearby WSMR weather stations.

3.4 Flight Plan

Generally, the flight plan required not only to obtain meteorological data as a function of altitude but to also spend as much time as possible at specific altitudes in order for the particulate samplers to capture a sufficient number of particulates for reliable analysis. Based on an ASL request, the flight plan also included flying along a constant altitude trajectory approximately 100 feet above the ground surface for the purpose of obtaining information on variability of Cn^2 and scattering as measured by the nephelometer.

3.5 Flight Data

The experimental data obtained from the flights of August 30 and 31 are summarized in the following subsections. Emphasis has been placed on optical and meteorological parameters.

3.5.1 Atmospheric Temperature

Figs. 3.1 and 3.2 show the temperature and altitude as a function of time for the August 30 and 31 MAP flights. Referring to the altitude profile, it can be seen that the August 31 flight yielded a smoother flight path than that of August 30. On both of these days, the same pilot flew the plane and an electrostatic stabalizer was used to help stabalize the plane in a horizontal trajectory. Therefore, the smoother flight of August 30 is attributed to the fact that the flight primarily occurred in a stable atmosphere above the mixing layer as compared to the flight of August 30th

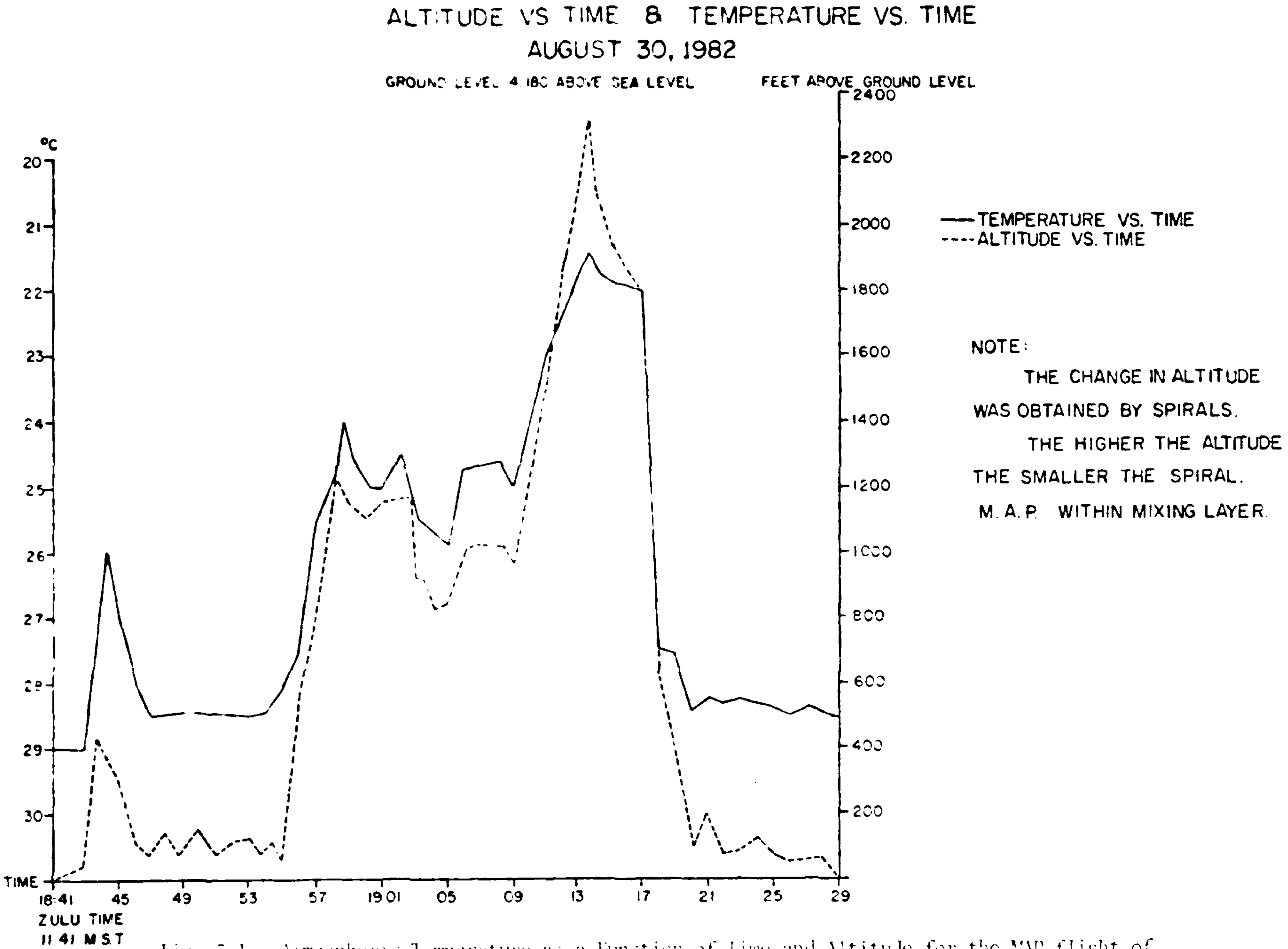


Fig. 5.1. Atmospheric Temperature as a Function of Time and Altitude for the MAP flight of August 30, 1982.

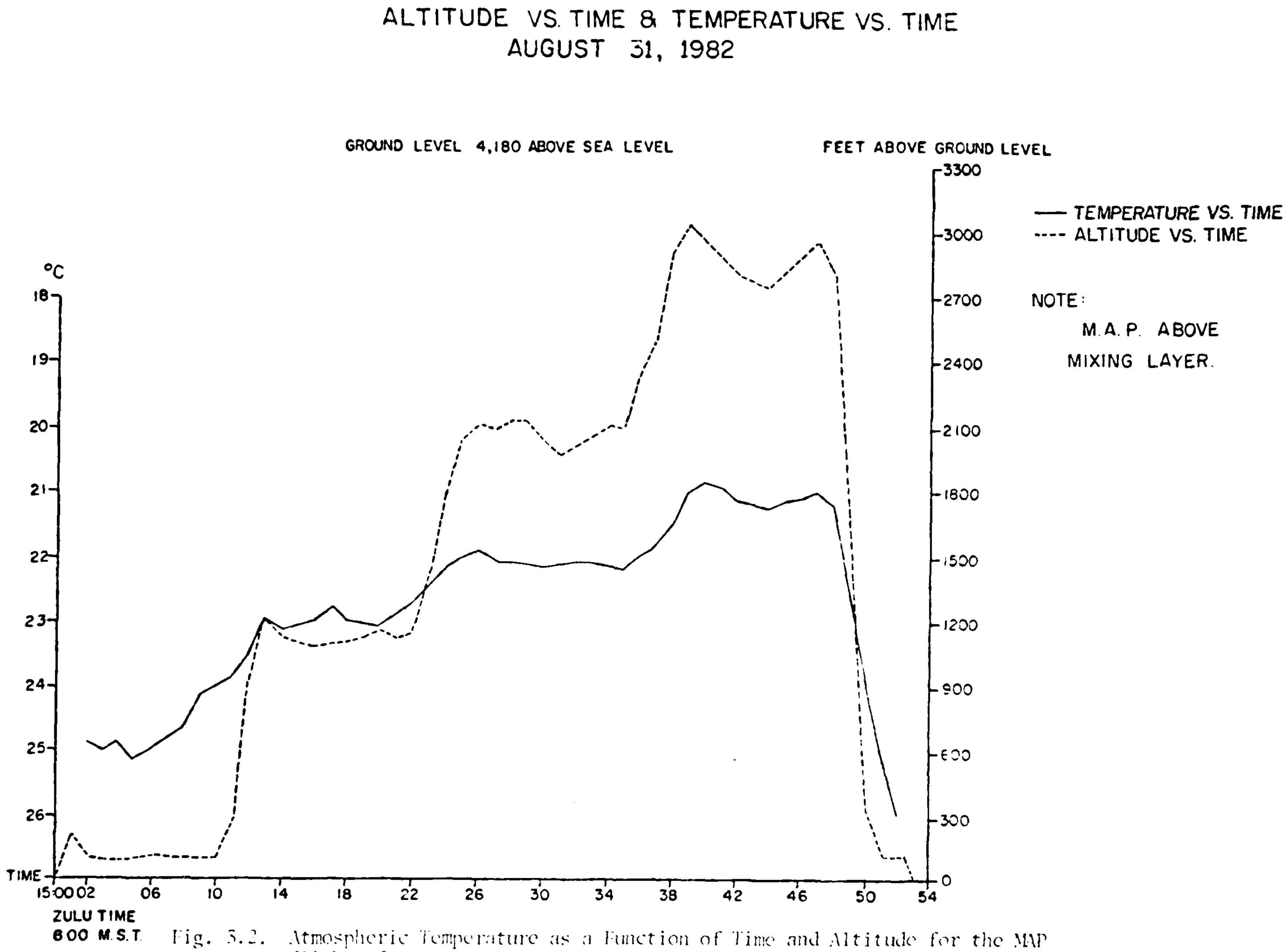


Fig. 3.2. Atmospheric Temperature as a Function of Time and Altitude for the MAP flight of August 31, 1982.

which occurred in the mixing layer. The temperature data for both of these flights corresponds within ± 0.7°C with the radiosonde data.

3.5.2 Atmospheric Pressure

The atmospheric pressure and corresponding altitude as functions of time are shown in Figs. 3.3 and 3.4 for the MAP flights of August 30 and 31, respectively. Again, the pressure as a function of altitude corresponds within ± 2 mHg with pressure data obtained from the range radiosondes.

3.5.3 Relative Humidity

Relative humidity as a function of time is plotted for the August 30-31 flights in Figs. 3.5. For comparison purposes, a standard radiosonde carbon hygrometer and a capacitance type (Vaisala) were flown. As shown in Fig. 3.5, the capacitance type humidity sensor demonstrated a faster response but it exhibits saturation, probably due to incident hydrometers.

3.5.4 Particulates

Typical SEM photomicrographs of particulate samples obtained during the flights are shown in Figs. 3.6, 3.7 and 3.8. Besides samples from the airborne PIXIE and UTEP samplers, a second PIXIE was also used to obtain near ground samples. The particle distribution for the ground PIXIE is shown in Fig. 3.9. The two slopes of this distribution indicate a bimodal distribution, probably due to the combination of desert and continental particulates.

Due to the short duration of the flights at a given altitude, small numbers of particulates were captured, precluding statistical reliable estimates of particle distributions. However, comparison of particulate samplerof the PIXIE and UTEP impactor with the ground reference indicate

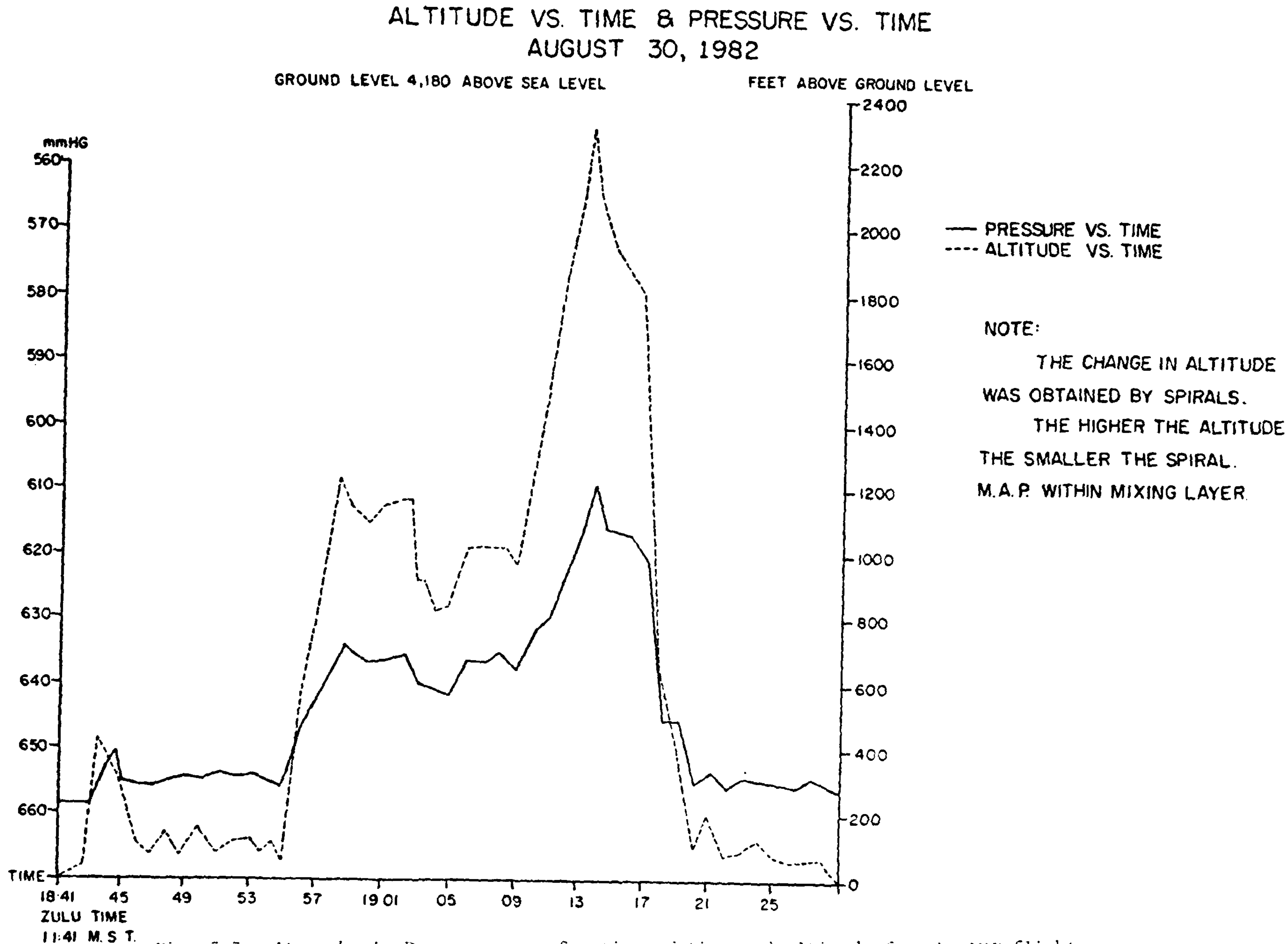


Fig. 3.3. Atmospheric Pressure as a function of time and altitude for the MAP flight of August 30, 1982.

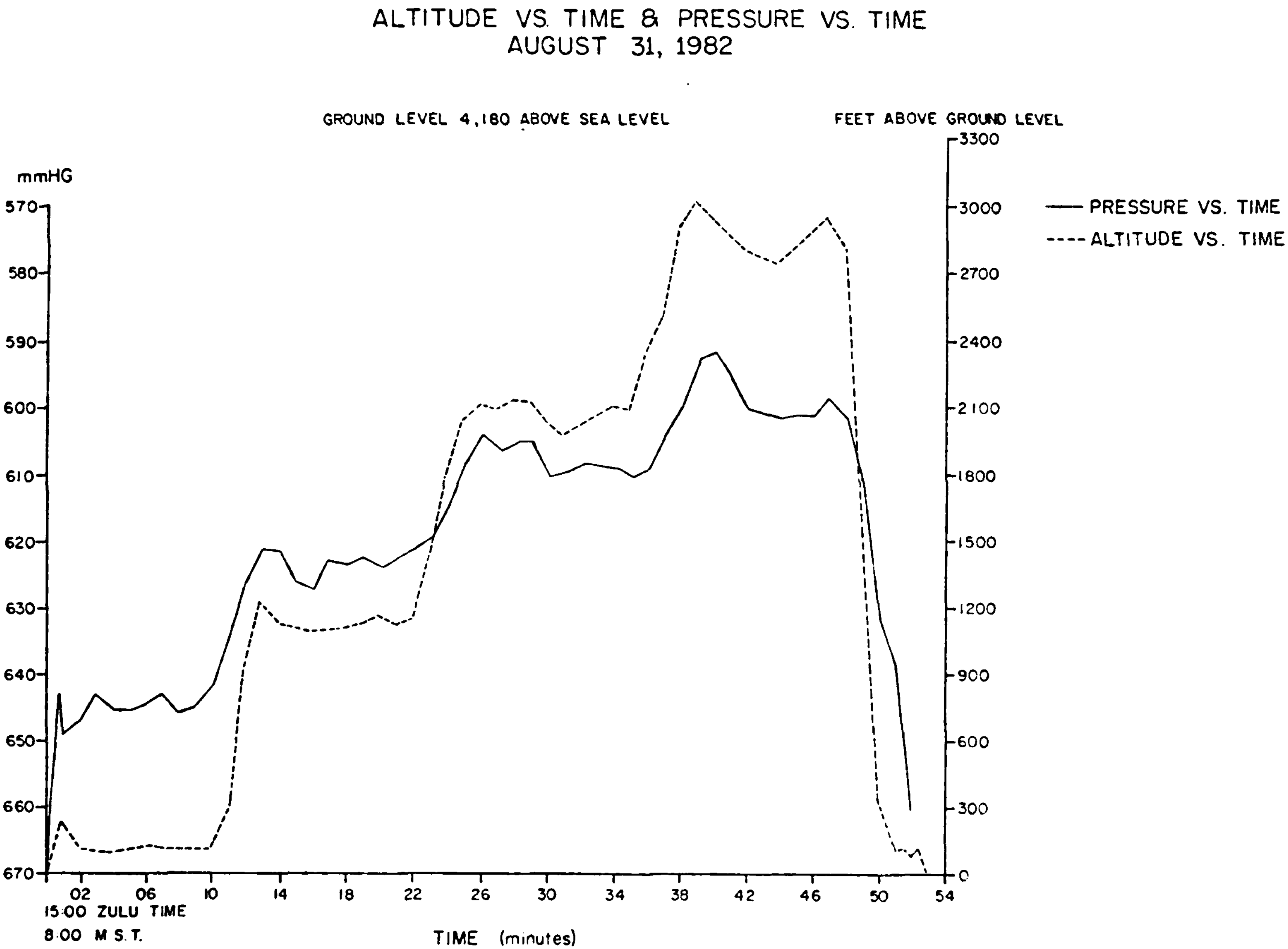


Fig. 3.1. Atmospheric pressure as a function of time and altitude for the MAP flight of August 31, 1982.

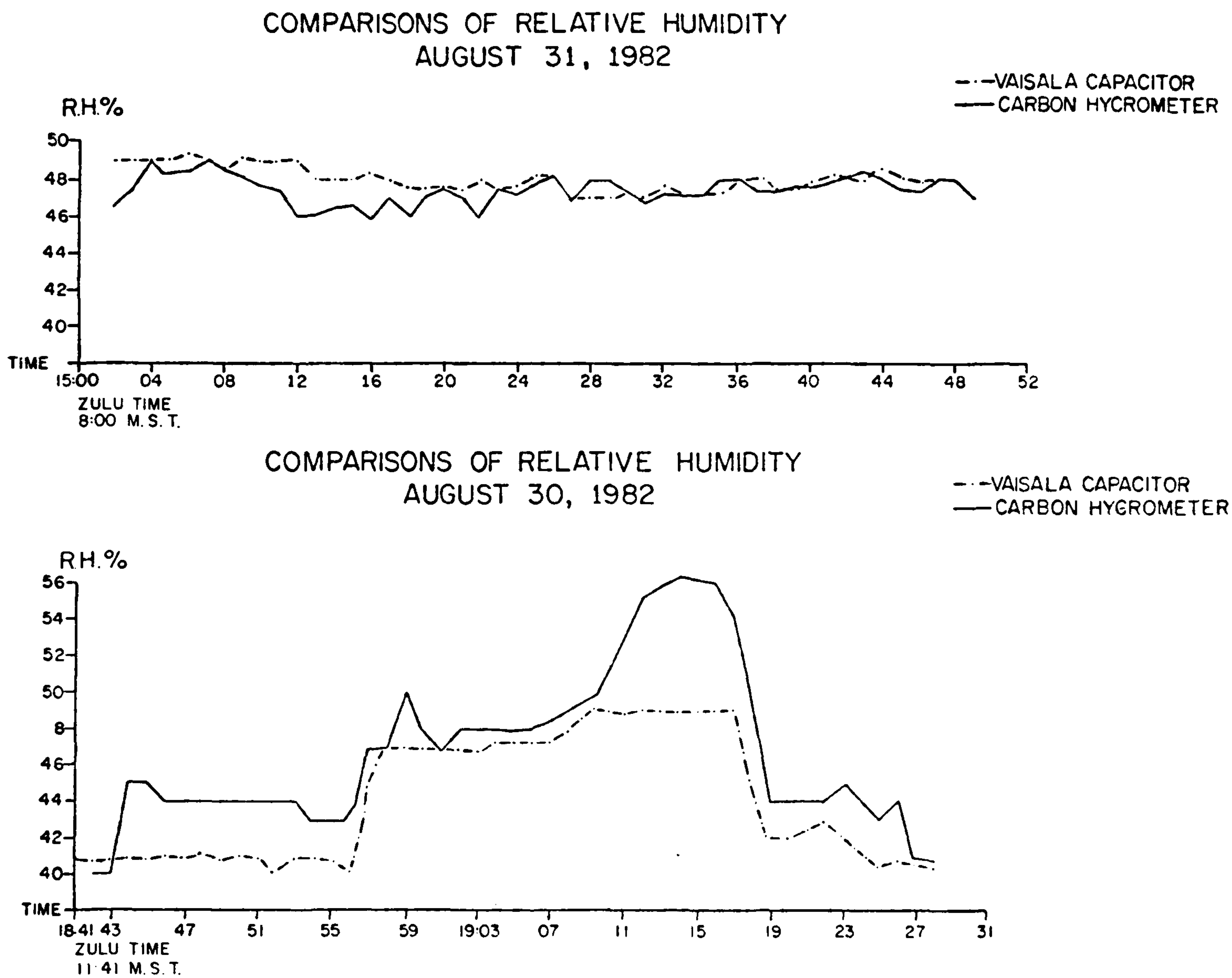
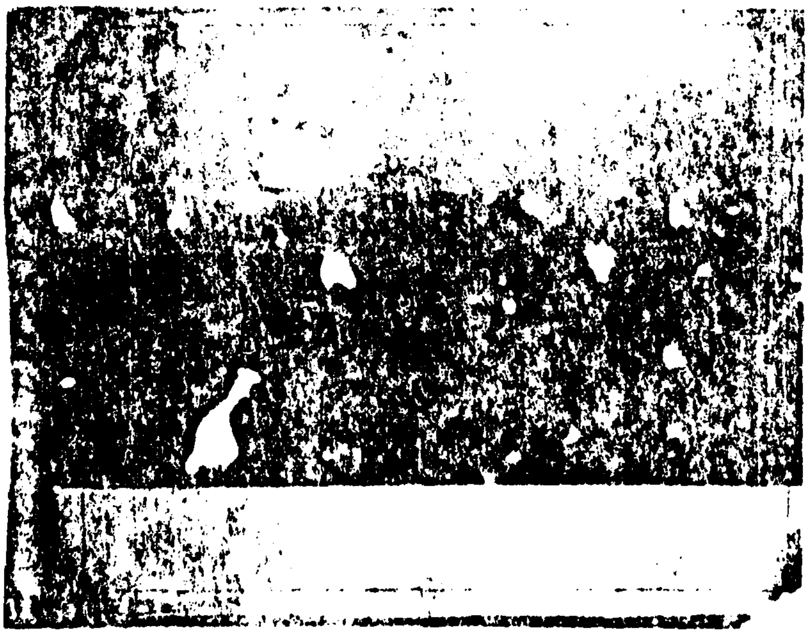


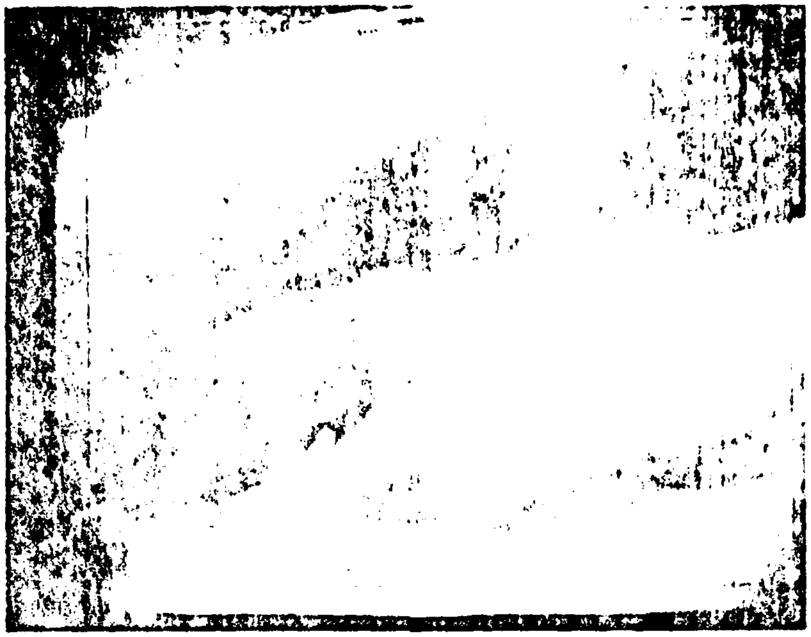
Fig. 3.5. Relative humidity measured by carbon hygrometer and Vaisala capacitor sensor for the flights of August 30 and 31, 1982.

Stage No. 1
(X2000)



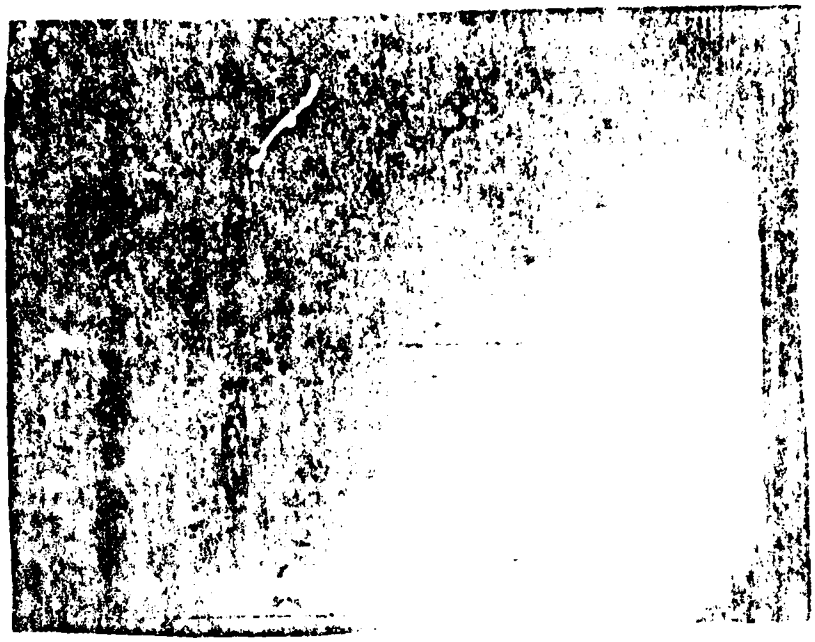
Stage No. 5
(X5000)

Fig. 3.6. SEM photomicrographs of stages one and five of the ground based PIXIE cascade impactor during the MAP flight of August 30, 1982.



Stage No. 2

Fig. 3.7. SEM photomicrographs of the stages one and two of the PIXIE cascade impactor on board the MAP during the flight of August 30, 1982.



Stage No. 5
(X50)

Stage No. 6
(X2000)

Fig. 3.8. SEM photomicrographs of the multistage impactor on board the MAP during the flight of August 30, 1982.

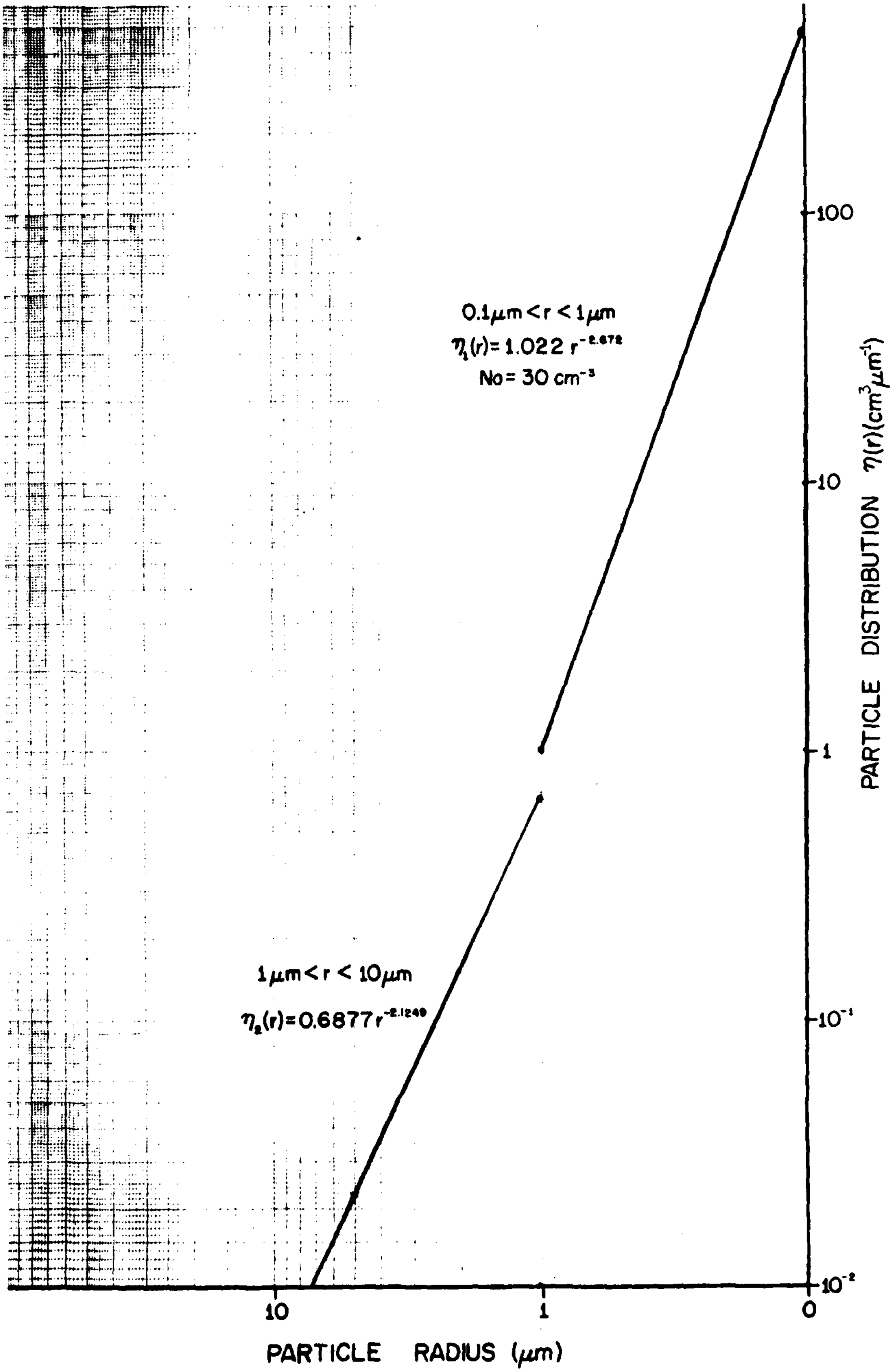


Fig. 3.9 Particle size distribution of the particulates captured by the ground based PIXIE cascade impactor during the MAP flight of August 31, 1982. The particle concentration measured 30 cm^{-3}.

that the flight impactors exhibited a cutoff below one micron due to non-isokinetic flow.

3.5.5. Nephelometer

The total scattering coefficients registered by the on-board nephelometer as a function of altitude are plotted in Figs. 3.10 and 3.11. Referring to Fig. 3.10, the measured light scattering up to 150 feet above the surface is plotted for the days of August 30 and 31. This difference is attributed to the mixing layer and surface inversion effect. For August 30, the mixing layer had completely developed when the flight took place around noon. During August 31, the earlier morning flight (8 a.m.), stability conditions prevailed with a near surface inversion (see Fig. 3.2).

The light scattering profile up to 3600 feet are shown in Fig. 3.11 for the flight of August 30. As shown in this figure, the scattering peaks are indicative of particulate stratification with respect to altitude. Similar stratification has been observed before with an integrating nephelometer on manned aircraft [5]. For August 31, light scattering above 150 feet was not obtained due to log amplifier cutoff resulting from a combination of very low scattering and drift of the nephelometer.

3.5.6. Optical Structure Function

The optical structure function, Cn^2 was determined from different temperature measurements with coiled 3 watt, 120 volt tungsten filaments serving as temperature sensors. Two sets of sensor pairs were located on the leading edge of the wing, each pair separated by 0.2 and 2.8 meters, respectively. The differential temperature measurements were first corrected for the sensor response time and variation of spatial energy distribution as a function of velocity [6]. This temperature correction is shown in Fig. 3.12 assuming a .030 second response time for the wire sensors.

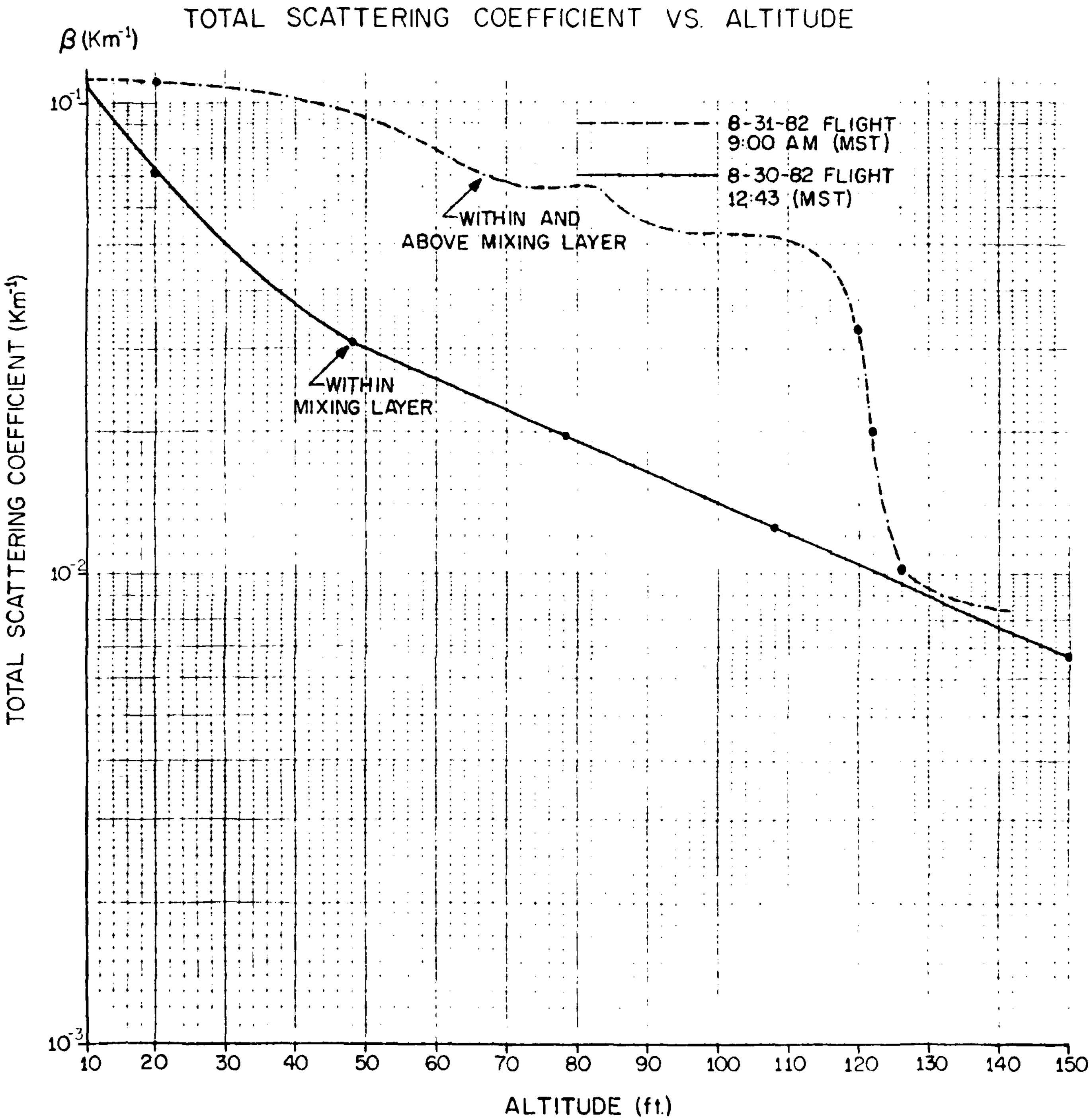


Fig. 3.10. Total scattering coefficients as a function of altitude as measured by the MAP nephelometer during the flights of August 30 and 31, 1982.

AUGUST 30, 1982

ALTITUDE VS MAXIMUM VOLUME SCATTERING COEFFICIENT

HSS NEPHELOMETER (0.88 μM WAVELENGTH)

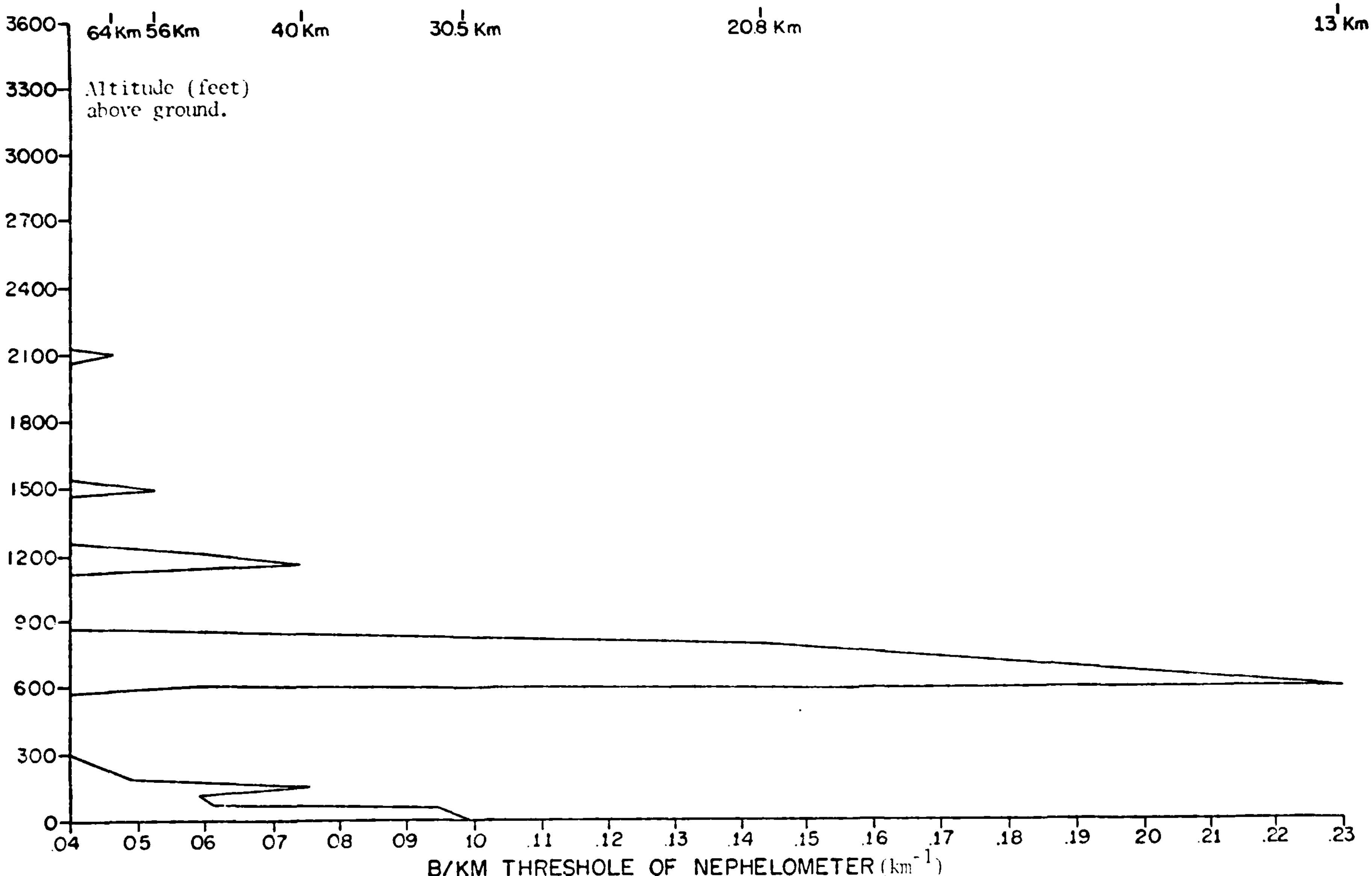


Fig. 3.11. Maximum total (volume) scattering coefficient as a function of altitude as measured by the MAP nephelometer during the flight of August 30, 1982.

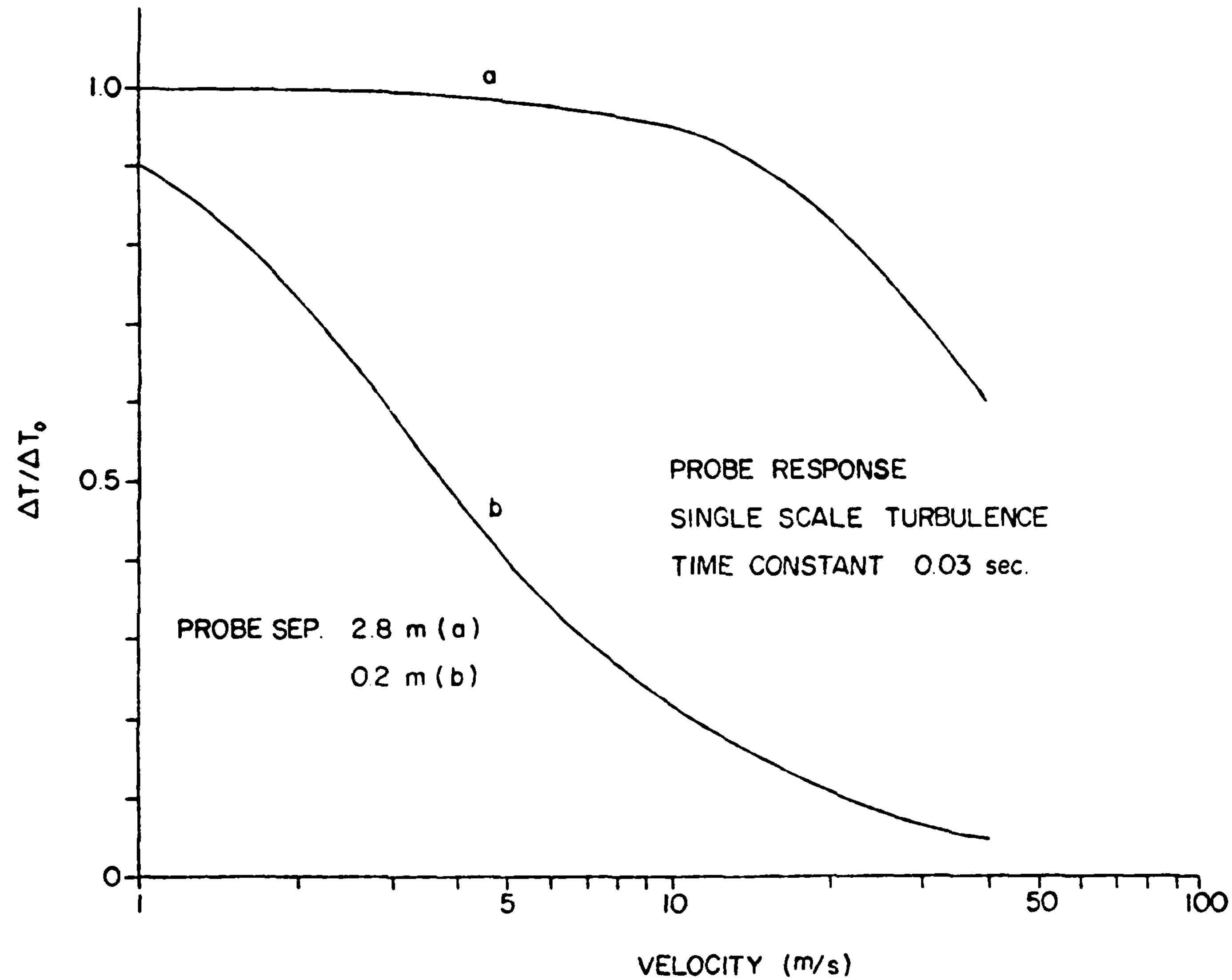


Fig. 3.12. Correction of differential temperature measurements as a function of MAP velocity due to the finite response time of the wire sensors [6].

The response time for the sensor used was .05 sec. [7]. The corrected rms temperature difference was then used to compute C_T^2 and C_n^2 in accordance to the following relations [8],

$$C_N^2 = [79\ P/T^2 \times 10^{-6}]C_T^2,$$

$$C_T^2 = (\Delta T)^2 d^{-2/3}$$

where

ΔT = rms corrected value of differential temperatures

P = atmospheric pressure (mb)

T = atmospheric temperature ($^{\circ}$K)

d = sensor separation (m) .

The plots of C_n^2 as a function of time are shown in Figs. 3.13 and 3.14, respectively. C_n^2 generally decreases with altitude, but stratification with respect to altitude also exists, similar to results obtained by previous experimenters [9].

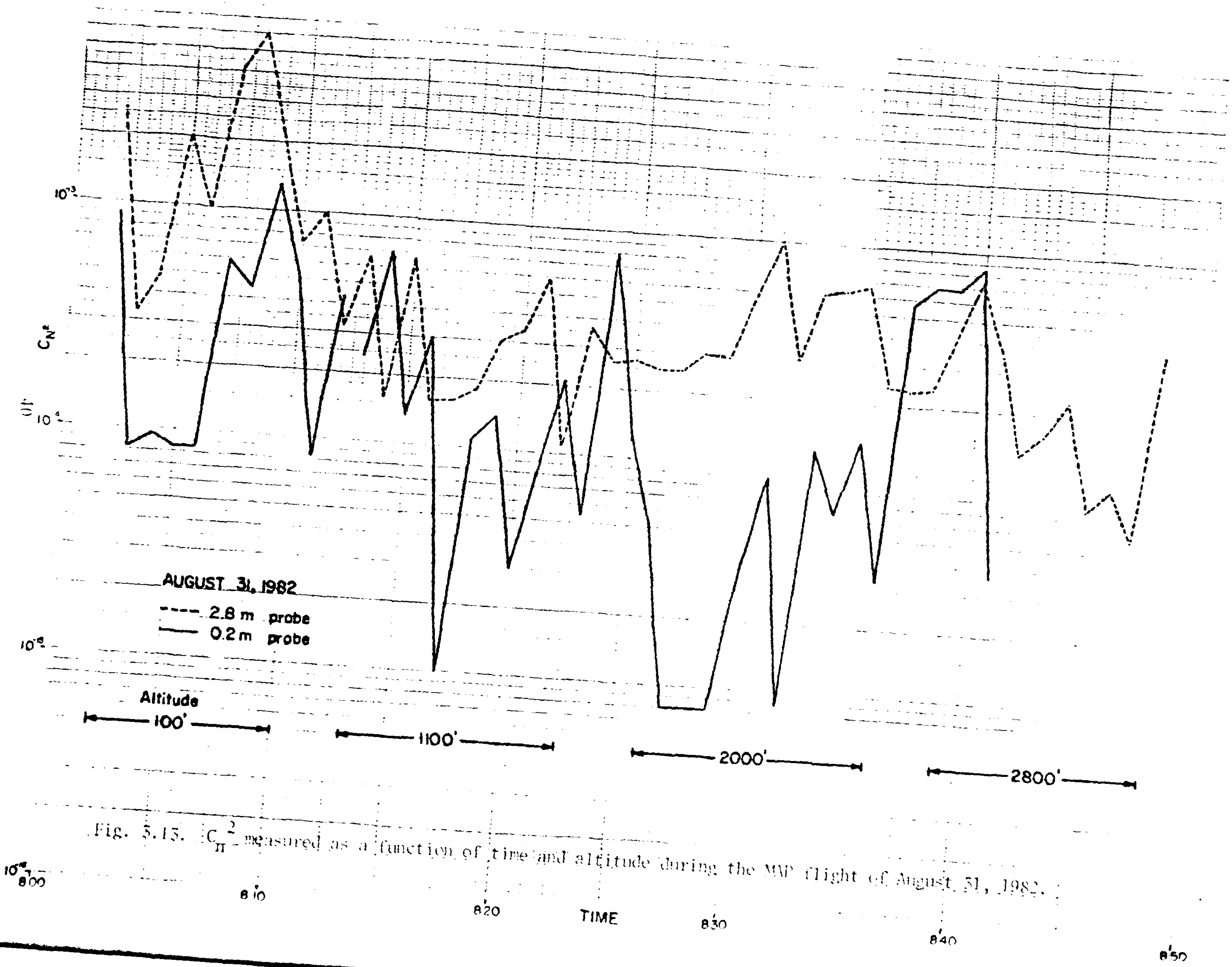


Fig. 5.15. C_n^2 measured as a function of time and altitude during the MAP flight of August 31, 1982.

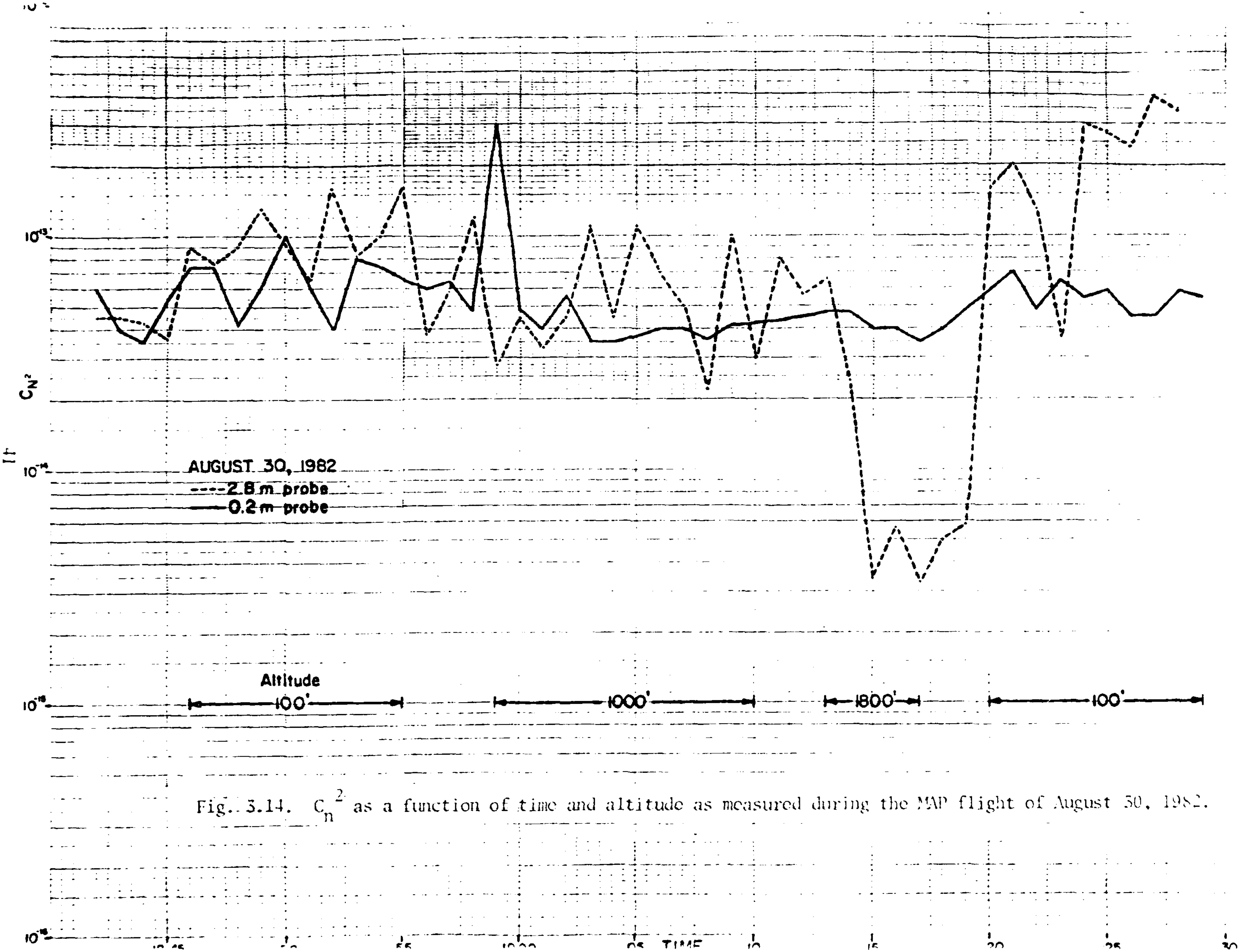


Fig. 3.14. C_n^2 as a function of time and altitude as measured during the MAP flight of August 30, 1982.

4. Conclusion

Based on this study and the flight results summarized in Section 3, it is concluded that a properly instrumented MAP may be utilized to characterize the meteorological, optical, particulate and turbulent characteristics of the atmosphere as a function of altitude or along designated paths.

In particular, the following conclusions and recommendations are made:

(1) The HSS VR101 may be used to measure the atmospheric scattering coefficients from .03 km^{-1} to 300 km^{-1}, corresponding to visibilities of 100 km and 10 m, respectively. This instrument is sensitive to the index of refraction of the aerosol and therefore has to be calibrated for the particular aerosol environment. It is recommended to calibrate it against an integrating nephelometer as this latter instrument's output is ideally dependent only the total backscattering coefficient derived from scattering in all directions. When calibrating or using this instrument in an enclosed location or near a surface, care must be taken to absorb the reflections by the use of baffles or other light absorption techniques. Fine structure of scattering can be detected by reducing the electronic time constant of integration.

(2) In reference to the particulate samplers, it is recommended that the cutoff below the one micron be extended by insuring that the air flow past the sensors be isokinetic. For the PIXIE cascade impactor, this may be accomplished by increasing the entrance diameter just enough to compensate for the deceleration of the air incident to the sampler entrance. In addition it should

also be located away from the boundary layer of the wing, obstructions and turbulence caused by the propeller. In the case of the UTEP sampler, the diameter of the sampler has to be reduced or other types of impactors for aircraft application may be employed.

(3) The capability and accuracy of the MAP can be enhanced by incorporating a PCM telemetry system. A PCM prototype flight system for the MAP has been designed [10]. It is based on use of a low power CMOS microprocessor. Different hardware configurations and sampling rates may be implemented by writing a program and storing on an EPROM.

(4) The ability to determine the horizontal wind component with out the use of radar tracking may be feasible with the MAP by utilizing an on board method of determining the ground speed of the plane in conjunction with other on board measurements of air speed and angle-of-attack. For his Master's Thesis, Gonzalez investigated the feasibility of utilizing the induction by the earth's magnetic field as an economical means of measuring ground speed on board the MAP [11].

(5) With the use of the MAP nephelometer to measured particulate scattering and C_T^2 measurements to determine the optical structure function, C_n^2, as well as mapping of meteorological parameters (particular air temperature), it is therefore possible to completely characterize the optical scattering and refractive properties of the atmosphere resulting from its aerosol, turbulent, and temperature structure.

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